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SOME EFFECTS OF TEMPERATURE ON DEVELOPMENT AND DIAPAUSE IN EGGS OF *MELANOPLUS BIVITTATUS* (SAY) (ORTHOPTERA: ACRIDIDAE)[1]

BY N. S. CHURCH[2] AND R. W. SALT[3]

Abstract

The normal hatching curve of postdiapause eggs of *Melanoplus bivittatus* (Say) at 25° C. is described and compared with those at 10, 15, and 20° C. The rate of postdiapause katatrepsic development was proportional to temperature; extrapolation showed 12° C. to be the theoretical threshold of normal development for this stage. However, restricted postdiapause development or conditioning occurred at 5° C. At 10° C., and less extensively at 5 and 15° C., partial development took place, resulting in deformed embryos.

Diapause, which is most readily broken at 5° C., may persist for more than 100 days at that temperature. It can also be eliminated at 25° C., but much more slowly. Alternating-temperature experiments disclosed no marked differences in the ease of diapause-breaking at various embryonic ages. The suggestion is made that temperature alternations hinder diapause-breaking and morphogenesis.

The threshold of development concept is briefly discussed with regard to some of the observations reported.

Introduction

Most eggs of the two-striped grasshopper, *Melanoplus bivittatus* (Say), when reared under favorable conditions, cease morphogenesis at the stage normally reached in 21 days of incubation at 25° C. with access to abundant moisture (2). During the next few days they gradually enter a state of diapause. Such eggs will be called *mature* diapause eggs. Under natural conditions the cold of winter breaks diapause, and postdiapause development commences in the spring. In late autumn, however, cold weather, sometimes combined with dryness, often stops development well before the 21-day stage. When this happens, the potential for diapause is broken in the same manner as is diapause in mature diapause eggs. The term *diapause-averted* will be used for eggs from which the diapause potential has been eliminated before the 21-day stage.

Tests conducted by the authors have disclosed no method of hastening diapause elimination in this species other than exposure to cold. The most efficient diapause-breaking temperature is near 5° C.; above or below this the reaction is slower.

[1] *Manuscript received December 20, 1951.*

Contribution No. 2910, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] *Assistant Entomologist, Field Crop Insect Laboratory, Lethbridge, Alta.*

[3] *Senior Entomologist, Field Crop Insect Laboratory, Lethbridge, Alta.*

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Further investigations made from 1948 to 1951 into the effects of moderate temperatures on diapause and development of *M. bivittatus* eggs are reported herein.

Materials and Methods

Eggs were obtained from two sources. Adult grasshoppers were collected from a field near Lethbridge, Alta., and caged in a greenhouse. Eggs were removed daily and incubated as long as was desired at 25° C., the incubation temperature used consistently in this work. Supplementary supplies of diapause-averted eggs were obtained in April or May from the same area as the adults and stored at 2° to 4° C.

In young eggs embryonic age was determined by dissecting a sample from each pod. The age of those 16 days or older was established from the position of the eye, readily seen through the chorion when wet.

An individual unit in any experiment consisted of 100 to 1000 eggs. They were generally reared in Petri dishes on blotting paper disks moistened with 0.1% sodium propionate solution, a mold inhibitor. Diseased eggs were discarded and papers and dishes renewed frequently to further discourage fungi and bacteria. Despite these measures mortality accompanying some lengthy treatments approached 30%, though it stayed below 10% in shorter ones. Constant temperatures were maintained within ± 0.5° C.

Influence of Temperature on Postdiapause Development

Normal Development at 25° C.

If a group of mature diapause eggs is given sufficient cold conditioning to break diapause, but not an excess amount, hatching generally begins on the sixth day of incubation at 25° C. It attains its maximum rate between the 10th and 13th days and is finished before the 25th. The eggs used and their previous treatment modify the shape of the hatching curve, but usually within these limits.

Threshold of Development

Sixteen-day diapause-averted eggs were selected from a field collection that had been stored at 2° to 4° C. for one month. Those of Series *A*, divided into four units, were kept at 10, 15, 20, and 25° C. until hatching was complete. The relative rates of development were computed in three ways, the criteria being the peak of hatch, 50% hatch, and 70% hatch. The rate at 25° C. was considered as unity. Fig. 1 shows the similarity in the results obtained by the three methods.

The same procedure was followed with Series *B* (Fig. 2), except that the 16-day eggs were given a further nine-day incubation before treatment to bring them to the verge of hatching.

Series *A* shows that after blastokinesis, which occurs on the 15th day at 25° C., the rate of development is directly proportional to temperature between 15 and 25° C. Development at 10° C. was only partial, producing abnormal embryos, and for the present is regarded as nonexistent. It will be discussed

in detail later. It should be noted that even at 15° C. development was not always complete. In Fig. 1, projection of the rate-of-development line to the zero-development point establishes the theoretical threshold of normal deve-

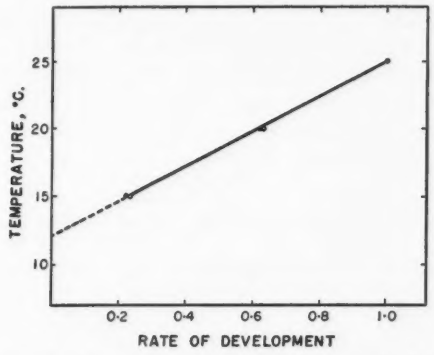

FIG. 1. Relative rates of development at 10, 15, 20, and 25° C. of 16-day diapause-averted eggs of *M. bivittatus*, based on the rate at 25° C. being equal to unity. Dots: rate at which eggs attained peak of hatch. Circles: rate at which they attained 50 and 70% hatch (coincidental).

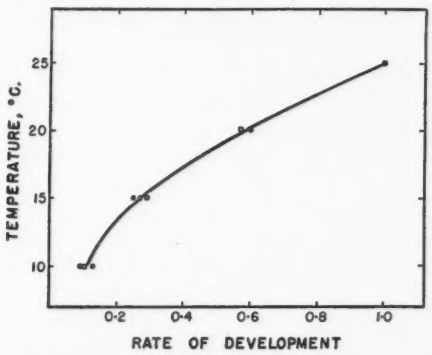

FIG. 2. Relative rates of development at 10, 15, 20, and 25° C. of eggs on the verge of hatching, based on the rate at 25° C. being equal to unity. Dots: rate at which eggs reached 50% hatch; squares: 70% hatch; circles: peak of hatch.

lopment at 12° C. But embryos that were not far from hatching, as in Series *B*, were often capable of finishing development at temperatures as low as 10° C. At this temperature some were too inactive to break out of the yellow cuticle and chorion after having digested the white cuticle, but an equal number did manage to hatch.

The actual threshold of development, then, depends upon embryonic age and the physiological reactions then at work. More information on this matter is given in succeeding sections. However, 12° C. will serve as the minimum temperature at which most eggs will undergo katatrepsis and that figure will be used in this paper.

Developmental Activity at 5° C.

From the data of three diapause-breaking tests employing mature eggs it was noted that additional exposure to 5° C., beyond that necessary to dispose of diapause, reduced the postdiapause incubation period. Hatching was compressed into a shorter period and the hatching peak, which without the added cold treatment occurred not earlier than the ninth day of incubation, was advanced to the seventh. The first individuals to hatch did so on the fourth day rather than the usual sixth. A typical case is presented in Table I; in this 40 days at 5° C. was adequate to break diapause in every egg.

TABLE I

DAYS AT 25° C. REQUIRED BY MATURE EGGS OF *M. bivittatus* TO REACH HATCHING PEAK AFTER EXPOSURES TO 5° C.

Days at 5° C.	Days to peak of hatch at 25° C.
50	10
75	10
100	8
125	7
150	7

It is concluded that certain processes essential for postdiapause development can proceed slowly at 5° C., but the activity cannot continue indefinitely. No visible morphological changes are entailed.

Sixteen-day diapause-averted eggs selected from a field collection were incubated for nine days at 25° C., to bring them close to hatching, whereupon they were exposed for zero, one, two, and four weeks to 5° C. and then reincubated. There were no differences in the hatches of the four groups. The treatments were not harmful, but even four weeks at 5° C. failed to reduce the prehatching incubation period. The hatching peaks occurred on the eighth or ninth day at 25° C. after the 21st embryonic day. The prehatching periods were neither as long as possible (10 to 13 days at 25° C.), which would have shown definitely that they had not been decreased by conditioning at 5° C., nor as short as possible (seven days), which would have shown definitely that they had been decreased. Hence it is uncertain which alternative is true. If there were a reduction, the processes producing it would have been completed in the overwintering eggs when they were 16 days or younger. If there was no reduction it was because these processes could not proceed in 16-day or younger embryos or in those about to hatch. In either case the test confirmed that the extent of postdiapause conditioning or development at 5° C. is limited.

Abnormal Development Near the Threshold

Abnormal development at moderately low temperarures was first noted at 5° C. Sixteen-day eggs from the same batch as those used in the experiment

from which Fig. 1 was derived were kept at 5° C. for 0, 7, 14, and 28 days, and then incubated for hatch. Some embryos failed to hatch and were found to be deformed. After 0 days at 5° C., 9% were abnormal; 7 days, 21%; 14 days, 37%; and 28 days, 43%. The longer exposures were most destructive.

When hatching had ceased in the experiment represented in Fig. 1 (in which 16-day diapause-averted eggs were held at 10, 15, 20, and 25° C.), eggs remaining unhatched were dechorionated with sodium hypochlorite. Examination showed most of them to be deformed. Deformed embryos were as prevalent in samples of eggs taken on the 35th day at 10° C. as at the end of the exposure on the 95th day, but they were not so badly misshapen. The final disposition of the eggs in this experiment is outlined in Table II. Storing the eggs at 2 to 4° C. before the experiment was possibly responsible for deformation of some embryos at 20 and 25° C.

TABLE II

PERCENTAGES OF DIAPAUSE-AVERTED 16-DAY EGGS HATCHED, DEFORMED, AND NORMAL WHEN KEPT AT TEMPERATURES INDICATED

Temperature, °C.	% Hatched	% Deformed	% Normal, unhatched
10	0	95	5
15	74	26	0
20	90	10	0
25	93	7	0

Abnormal embryos exhibit a variety of intergraded forms. If cold treatment is applied before the end of blastokinesis, embryos may be unable to finish revolution. They slowly acquire many characteristics of 18- to 20-day embryos, but remain small, retaining a U- or J-shape. Some eventually become extremely grotesque. Often, an embryo almost 17 days old when exposed remains shorter than the egg, and completes dorsal closure without engulfing all of the yolk. Some develop normally in most respects, their eyes darken as they should, but the femora do not grow past the fourth or fifth abdominal segment.

The few eggs that were apparently normal after 95 days at 10° C. proved to be so, for they hatched when removed to 25° C. Deformed embryos were incapable of hatching at any temperature.

Ten degrees centigrade is most hazardous; 5 and 15° less so; and 0, 20, and 25° C. quite innocuous. At 0° C. all development is suspended, but progressively higher temperatures support increasingly more reactions, until at 20° C. all components of development can proceed normally. Intermediate temperatures, 10° C. for instance, permit certain growth processes only. The inevitable result is irregular growth. Eggs vary considerably in their reactions to these borderline temperatures. Some are safe at 5° C. because activity is suspended; most, but not all, are safe at 15° C. because they complete development and hatch normally.

In their natural environment, of course, 15 to 18-day eggs are seldom subject to prolonged constant temperatures near 10° C. Hence this laboratory-produced phenomenon is probably not of much practical importance; nevertheless, it is of considerable biological interest.

Influence of Temperature on Elimination of Diapause

Frequent Absence of Diapause

In this work care was taken to distinguish between the majority of eggs, which have a diapause, and others which omit this interruption of morphogenesis. The co-existence of the two types in the same egg population was illustrated by an experiment in which the temperature was alternately efficient for development and for diapause-breaking. Eighteen sets of newly laid eggs were started incubating at 25° C., one set being removed daily, the last on the 17th day, and subjected to 5° C. and 25° C. on alternate days. The combined hatch from the 18 sets that occurred during each total of two days at 25° C. plus two days at 5° C. was expressed as a percentage of the final hatch, and plotted against the number of days at 25° C. experienced by the eggs. A bimodal graph was obtained (Fig. 3).

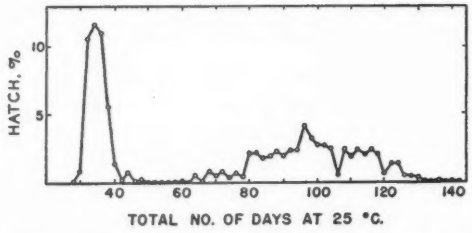

FIG. 3. Hatch, expressed as percentage of total hatch, of eggs alternately one day at 25° C. and one day at 5° C. Time at 5° C. omitted.

It is unlikely that eggs composing the first wave of hatch, which reached its peak on the 34th day at 25° C., received appreciable advantage from their 5° C. treatment because they experienced most of it during the period of development that would succeed any diapause. The 34-day incubation period preceding the first hatching peak is comparable to that of eggs that have had diapause broken by sufficient, but not excessive, exposure to cold. Therefore it is evident that this first mode represents non-diapause eggs.

The relative abundance of non-diapause eggs differs widely from season to season. Of the eggs laid in the greenhouse from June 19 to July 18, 1948, 43% were non-diapause; from July 23 to Sept. 14, 1949, 0%; and from July 4 to Sept. 30, 1950, about 8%. All proportions of the two types are to be found in individual pods.

Casual observations indicate that there is a greater proportion of non-diapause eggs in a population as the laying season progresses. In a population of diapause and non-diapause eggs the mean duration of diapause decreases

toward the end of the season. This may or may not be what Burdick (1) referred to in the statement that there was a decrease in the *average* length of diapause in later laid eggs of *M. differentialis* (Thos.). In *M. bivittatus*, at any rate, the length of diapause in the diapause eggs did not decrease; rather, the mean diapause duration decreased because there were relatively fewer diapause eggs later in the season.

Duration of Diapause at 5° C.

In large samples, non-diapause eggs being omitted, the portions in which diapause is broken by cold treatment produce a normal sigmoid curve when plotted against exposure length. The time required to eliminate diapause in individuals covers a broad range; one egg may require a few days at 5° C. and another more than 100.

Marked differences in the persistence of diapause also were found from year to year in eggs laid in the greenhouse. For its elimination from 50% of the eggs, 100 days at 5° C. were required by the 1949 brood and fewer than 30 by that of 1950.

Diapause Elimination at a Warm Temperature

Any diapause remaining, after insufficient exposure or no exposure to low temperature, is eliminated at temperatures as high as 25° C.; however, the reaction is slow. When a group of eggs is given a short cold treatment, and then incubated, those eggs for which the cold treatment is ample hatch *en masse* as previously described. The remainder, if retained at 25° C., continue to hatch sporadically for months as they emerge from diapause. Hence, prolonged exposure to 25° C. preceding cold treatment would logically be expected to shorten the cold period necessary for diapause-breaking. Such is actually the case. Table III lists the percentages of grasshopper eggs in which diapause was broken when newly laid eggs were given (1) 40 days of incubation at 25° C.,

TABLE III

PERCENTAGES OF EGGS IN WHICH DIAPAUSE WAS BROKEN BY INDICATED EXPOSURES TO 25° AND 5° C.

Series *A* Incubated 40 days at 25° C. before cold treatment		Series *B* Incubated 86–100 days at 25° C. before cold treatment	
Days at 5° C.	Diapause elimination, %	Days at 5° C.	Diapause elimination, %
25	70	0	13
50	100	5	31
75	100	10	57
		15	88
		20	100
		25	100

plus 25, 50, or 75 days at 5° C. (Series *A*); (2) 86 to 100 days at 25° C., plus 0, 5, 10, 15, 20, or 25 days at 5° C. (Series *B*); followed in each case by reincubation. Hatching within the first 25 days of reincubation was taken to mean that diapause had been broken. Eggs in Series *B* were kept an average of 53 days longer at 25° C., after which they needed about 16 days less at 5° C. than did Series *A* to effect diapause-breaking in 85% of them (estimated from data in Table III). Thus at 25° C. diapause was dissipated, but only one-quarter to one-third as rapidly as at 5° C. in this batch of eggs. From Burdick's (1) data on *M. differentialis* approximately the same ratio can be estimated.

An alternative explanation of the shorter cold treatment required by Series *B* is as follows: diapause-breaking at 5° C. may be faster in older eggs because in the course of their added time at 25° C. they have undergone some conditioning action other than diapause-breaking that makes them more receptive to cold treatment. Inasmuch as it is already known that diapause can be completely dissipated in eggs held continuously at 25° C., the explanation adopted in the preceding paragraph is the more attractive.

Effects of Alternation of Temperature on Development and Diapause

Diapause-breaking and Embryonic Age

To demonstrate whether embryonic age affects the rate of diapause-breaking, the data of Fig. 3 were reorganized on the basis of two age-groups (Fig. 4). Further division was impractical because of variation among sets.

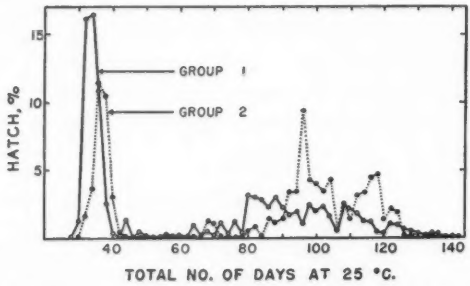

FIG. 4. Hatch, expressed as percentage of total hatch, of eggs alternately one day at 25° C. and one day at 5° C. Time at 5° C. omitted. Group 1: incubated at 25° C. for 0–8 days before alternation; Group 2: incubated 9–17 days.

Group 1 consisted of the nine sets incubated 0 to 8 days before the temperature was alternated; Group 2, the remaining nine, were incubated 9 to 17 days. By any specified day at 25° C. eggs in Group 1 experienced, on the average, nine days more at 5° C. than eggs in Group 2. Hatching of the first group's diapause eggs preceded that of Group 2 by seven or eight days at 25° C. and succeeded it by one or two days at 5° C. The extra day or two at 5° C. is accounted for by the fact that some diapause-breaking took place in Group 2 eggs in the course of their additional seven or eight days at 25° C.

The non-diapause eggs in Group 1 hatched four days earlier than those of the second group, no doubt because the previously mentioned conditioning processes proceeded during their additional few days at 5° C.

A modification of the last experiment was performed with another season's eggs, eliminating the unnaturally sudden temperature changes. Four groups of eggs laid in the greenhouse were used. Preliminary incubations preceding temperature-alternation were, for Group 1, 1–10 days; Group 2, 14 days; Group 3, 20 days; and Group 4, 32–40 days. They were then reared in vials

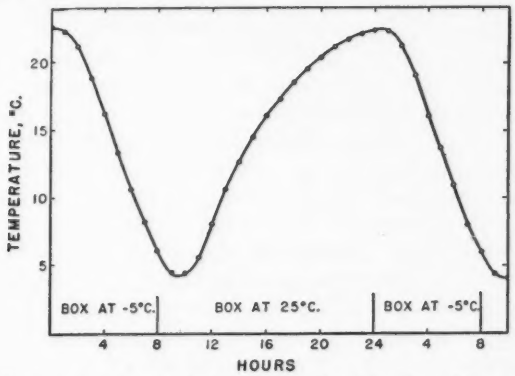

FIG. 5. Daily temperature record of eggs in insulated box kept 8 hr. at −5° C. and 16 hr. at 25° C. each day.

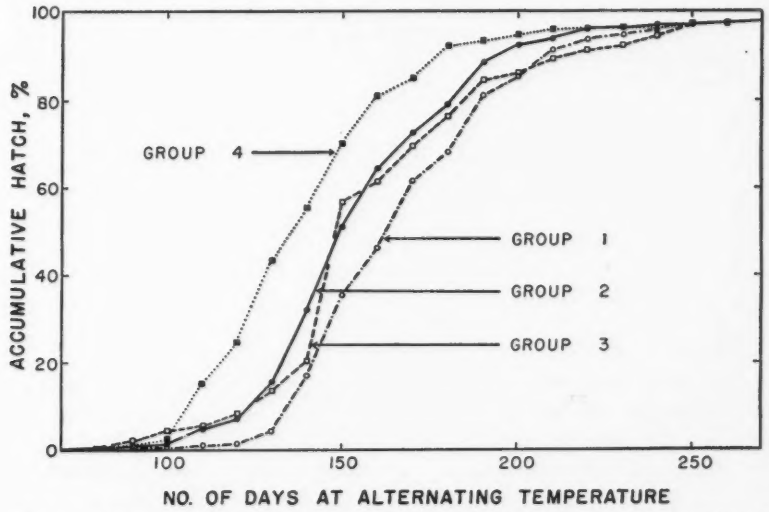

FIG. 6. Accumulative hatch, expressed as percentage of viable eggs, of eggs subjected to temperatures shown in Fig. 5. Non-diapause eggs omitted. Group 1: incubated 1–10 days at 25° C. before alternation; Group 2: incubated 14 days; Group 3: 20 days; Group 4: 32–40 days.

of moist soil placed in a box insulated with 4 in. of cork. The box was kept daily at −5° C. for 8 hr. and at 25° C. for 16 hr. The temperature of the soil, as measured by a thermocouple, followed the curve in Fig. 5, giving the eggs a daily equivalent of one-third of a day at 25° C. (based on degree-hours above 12° C.) for development, plus the equivalent of at least half a day at 5° C. for diapause-breaking.

In Fig. 6 the accumulative hatch, expressed as percentage of viable eggs in each group, is plotted against the number of days at alternating temperatures. The few non-diapause eggs present were omitted. Group 4 was given an average of 16 days at 25° C. more than Group 3; Group 3, 6 days more than Group 2; and Group 2, 9 days more than Group 1. As diapause-breaking at 25° C. is considerably slower than at the alternating temperatures of the treatment, the differences in the hatching times recorded in Fig. 6 are somewhat greater than one would predict. If, as suggested in the following section, alternation of temperatures has a retarding effect, then the predicted differences would be magnified, as they are in Fig. 6. In this experiment alternations were more frequent than in the previous one, and temperature changes were gradual. The irregularity of Group 3 has not been explained.

The omission of cold treatment until embryos were of various ages had no significant effect on the rate of diapause elimination in either experiment. The cold exposures were intermittent, and morphogenesis was permitted throughout, but if diapause-breaking were remarkably quicker at a certain embryonic period it would have been evident. Less-marked tendencies could have been obscured, however.

Retarded Development

Alternation of warm and cool temperatures does not stimulate either diapause-breaking or postdiapause development. Rather, there is some evidence that constant temperatures are more efficient, most noticeably for diapause-breaking.

The same egg supply was used for the constant temperature experiment represented in Table III and the alternating-temperature experiment in Fig. 6. Eggs in the former (designated Experiment *A*) were kept on moist blotter, the latter (Experiment *B*) in moist soil, but this difference should not have had any noticeable effect. The two series of Experiment *A* were combined, as were the four groups of Experiment *B*, and average figures estimated for each. On the basis of the intervals from the time the eggs were 21 days old and the diapause-breaking equivalents of the temperatures in days at 5° C., the data in Table IV were obtained. (It was assumed that one day at 5° C. equalled three and one-half days at 25° C. or two days of the alternating temperatures for diapause-breaking. For development three days of alternating temperatures equalled one day at 25° C. In Experiment *B*, 33 days of alternating temperatures were deducted for post diapause development.) The table shows that diapause-breaking at the alternating temperatures is less than half as fast as at constant temperature. The difference is apparently greater than the experimental error.

TABLE IV

APPROXIMATE EQUIVALENT NUMBER OF DAYS AT 5° C. REQUIRED TO BREAK DIAPAUSE IN 50, 70, 90, AND 100% OF EGGS EXPOSED TO CONSTANT AND ALTERNATING TEMPERATURES

Experiment	Temperature condition	Approximate no. of days at 5° C.			
		50%	70%	90%	100%
A	Constant	30	35	40	45
B	Alternating	60	65	85	110+

Hatching outdoors, under the influence of naturally fluctuating temperatures, was later than anticipated on two occasions. In the first trial, 13-, 16-, 17-, 18-, 19-, and 20-day diapause-averted field-laid eggs were buried 1 in. below the soil surface under screen cages. Temperature observations with only approximate, but development seemed to be tardy when compared were controls incubated at 25° C. In the second trial six groups of 16-day diapause-averted eggs were buried, at 8-day intervals, ½ in. beneath the surface, adjacent to a recording thermocouple. Calculations of degree-hours showed the first group's hatch delayed by the equivalent of more than four days at 25° C., later groups progressively less so. Sampling indicated that development was particularly slow at an embryonic age of 19–20 days. Unusually frequent soaking rains that accompanied most of the treatment may or may not have been partly responsible. Yet in the laboratory, when incubation of a group of mature postdiapause eggs was interrupted by keeping them at 5° C. every second day, development and hatch per day at 25° C. kept pace with that of eggs continuously at 25° C. It should be noted, however, that temperature changes here were fewer than in the experiments reported above.

The evidence suggests that frequent temperature changes hinder developmental and diapause-breaking activity. This suggests that the commencement of a physiological process lags behind the arrival of the egg at a temperature that will support the process. At any rate it is clear that the influence of temperature is determined by more than the mere accumulation of the time–temperature product.

Discussion

The necessity for separate consideration of the relationship between temperature and diapause elimination on the one hand, and temperature and morphogenesis on the other, is indicated as a result of these experiments. Temperature optima for the two are separated by more than 20° C. in *M. bivittatus* eggs. To obtain results of any precision one must be yet more discriminating.

It was shown that between the end of diapause and the visible beginning of prehatching morphogenesis certain necessary events, which take place best at higher temperatures, will go on at temperatures as low as 5° C., whereas

the threshold of development for the over-all period of katatrepsis was calculated at 12° C. This figure represents the minimum temperature at which most such embryos can accomplish all aspects of development and hatching. But much can happen at temperatures below this threshold. And other factors, such as temperature constancy perhaps, must be considered. Further indication of the flexibility of temperature–development relationships with changing embryonic stage was the hatching of advanced eggs placed at 10° C., though younger eggs did not hatch at this temperature.

Partial, and consequently abnormal, development resulted from exposure to constant temperatures between 5 and 15° C. This is evidence that the many physiological reactions proceeding at one time have individual and somewhat different temperature–activity relations. In the 5–15° C. range lie the various minimum temperatures that will support them.

Moreover, individual eggs behave differently, exhibiting variations in their minimum developmental temperatures. Most eggs went normally through katatrepsis at 15° C. and some did not; many 16-day eggs developed abnormally at 5° C. and others displayed no change.

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A NEW APPARATUS FOR THE STUDY OF SEDIMENTATION IN LAKES[1]

By Herman Kleerekoper[2]

Abstract

An apparatus is described for the quantitative study of sedimentation at different levels in lakes. A tray of 1 sq. meter area receives the descending material. This tray can be tightly closed before lifting it from the water, by means of a hydraulic device. Because of the large area and very low borders (5 cm.), the collecting error produced by narrow deep vessels is avoided. Even in oligotrophic lakes, enough material can be collected during one week for microchemical analysis.

Introduction

In the course of his investigations on the mineralization of sediments in tropical lakes, the author has repeatedly felt the necessity of an apparatus by which relatively large quantities of sinking detritus could be collected within a short period, and at different levels in the water.

It is believed that the rate and thoroughness of mineralization of valuable nutrients contained in the dead plankton organisms and their waste products, which make up the bulk of the sedimentation in most natural lakes, is one of the most important factors in the biological productivity of lakes. Both the rate and the thoroughness of this mineralization determine to a great extent the availability of critical nutrients to the phytoplankton in the lake. More and more evidence is being accumulated to the effect that the mineralization of phosphorous compounds into phosphates is one of the most important phases in the nutrient cycles in lakes. The main purpose of the apparatus described is to follow the chemical and bacteriological events coupled with the mineralization of organic phosphorous compounds present in decaying plankton organisms.

Some workers used vessels placed on the bottom of the lake or suspended at different depths for collecting the so-called "plankton rain". The disadvantages of these collecting devices are mainly in their small area, and in their effect on the settling of suspended materials in turbulent regions of the lake. The border of the vessel acts very much like a snow fence, and increases the quantity of sediment collected in the vessel. The values for the rate of sedimentation are therefore too high, especially in turbulent regions of the lake.

The author designed an apparatus which reduces the collecting error, and allows the sampling of sinking detritus on an area of 1 sq. meter. The large collecting area of the apparatus makes short time observations possible which are particularly desirable in the study of the decomposition of phosphorous

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[2] *Director of the Biological Station of Mont Tremblant, Province of Quebec, and Associate Professor of Zoology, McMaster University, Hamilton, Ont.*

and nitrogenous compounds. The undesirable effect of the borders was reduced by keeping them low in proportion to the total collecting area. This approach required a device by which the collecting tray could be closed before hauling it to the surface without the loss of the material collected.

Description of Apparatus

The characteristics of the apparatus are shown in detail in Figs. 1 to 9.

The apparatus was constructed in the workshops of the Biological Bureau of the Department of Game and Fisheries of the Province of Quebec, by Mr. C. Gosselin, for investigations in the lakes of Mont Tremblant Park. The material used was "Alcan Aluminum". Brass and steel were used in the construction of the hydraulic pump.

Connections were made by welding or by means of cadmium-plated bolts and rivets. The use of other metals in contact with the aluminum must be strictly avoided in order to prevent electrolytic corrosion. All metallic parts were protected by zinc chromate paint covered by aluminum paint. The moving parts were coated with a water-resistant grease.

The apparatus consists of a square tray 100 × 100 × 5 cm. (39.4 in. × 39.4 in. × 2.0 in.), which is bolted onto a frame of aluminum angle of $\frac{1}{4}$ in. × 3 in. × 3 in. The sides of the frame carry grooves in which a lid rests as shown in Fig. 4. The lid has slightly larger dimensions than the tray and is powered by a hydraulic pump to which a rubber hose is connected. The length of this hose depends upon the maximum depth at which the apparatus is to be set. Under the hydraulic pressure, the piston (*A*, Figs. 1 and 2) will move forward and push the sliding lid (*B*, Fig. 1; *A*, Fig. 3) over the open tray in which the sediment has been collected. Very little pressure is necessary to close the lid which slides smoothly in the grooves of the vertical walls of the tray. Tilt of the collector by the displacement of the closing lid is avoided by weight *H* (Fig. 2; *F*, Fig. 3) which moves in the opposite direction by means of cable *K* (Fig. 2; *G*, Fig. 3; Fig. 9). It is important that the material used for the piston of the pump does not contain rubber, which has the tendency to expand laterally when under pressure. The expansion increases the friction very considerably, and causes failure of the closing mechanism. The grooves in the walls of the tray are made so that the lid closes the collecting tray tightly. In order to produce tight closure, the transverse end wall (*C*, Fig. 1; *B*, Fig. 3) is also provided with a groove whose lower side is slightly bevelled so that the advancing lid will enter the groove without difficulty. One extremity of the pump cylinder (*D*, Fig. 1; *C*, Fig. 3) is suspended on a pin (*E*, Fig. 1) which allows a vertical swing of the cylinder (see also Fig. 7). The cylinder is also loosely supported by a vertical strip of aluminum (*F*, Fig. 1; *D*, Fig. 3). The attachment of the piston rod to the sliding lid is also made flexible. At the four corners of the frame, hooks are placed to which cables can be attached. The total weight of the collector is 170 lb.

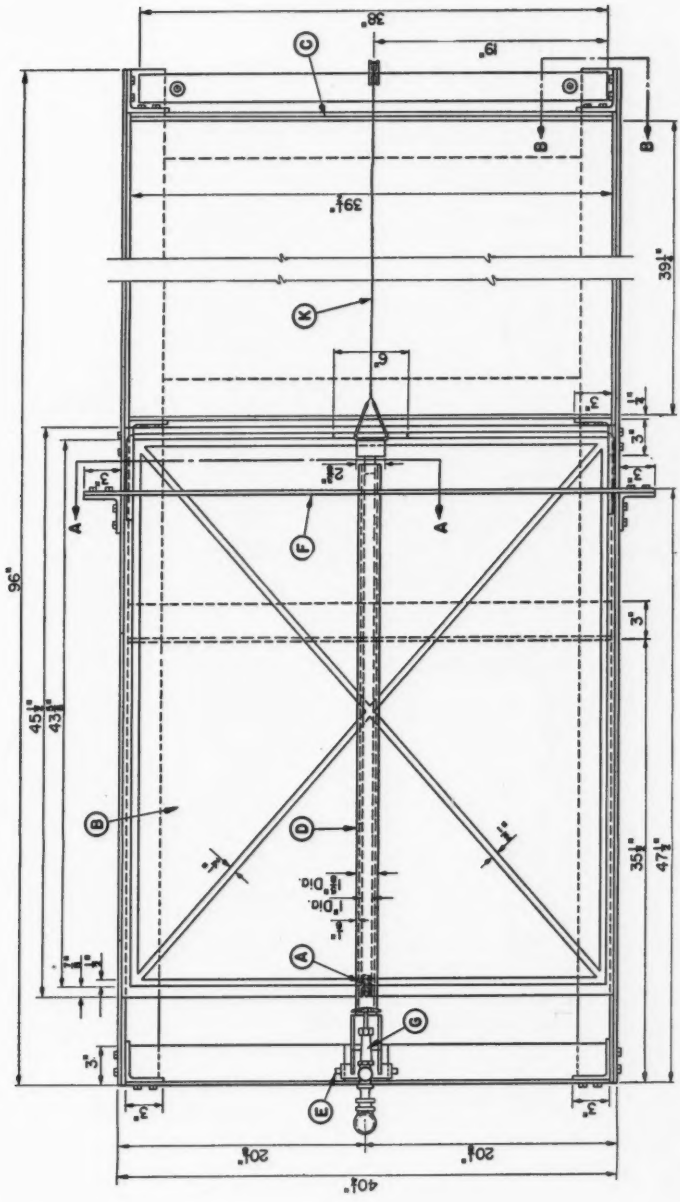

FIG. 1. Drawing showing construction details.

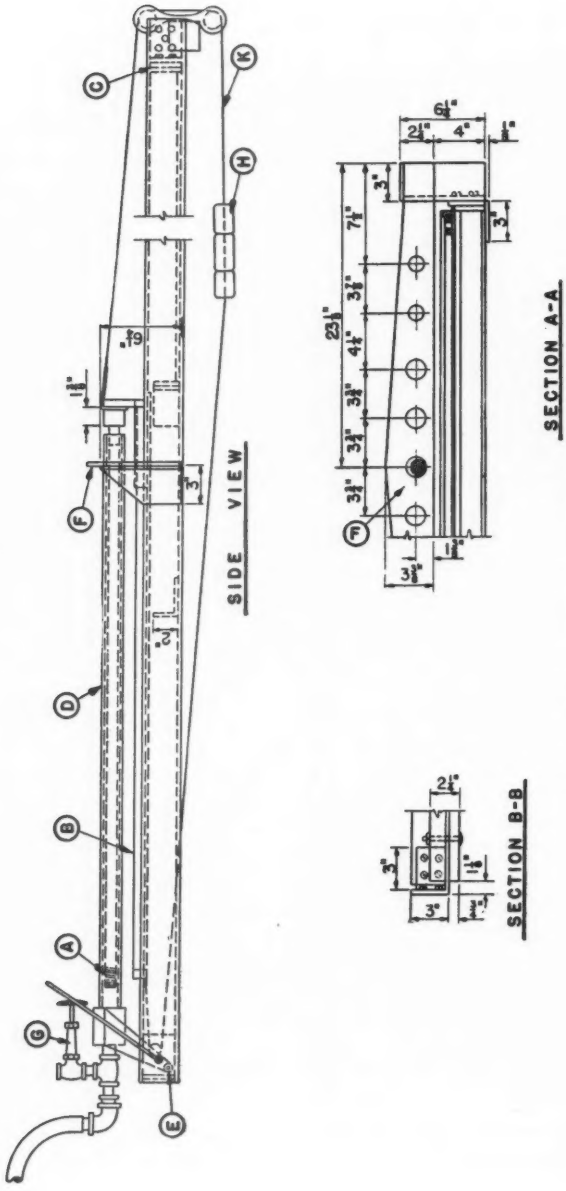

FIG. 2. Drawing showing construction details.

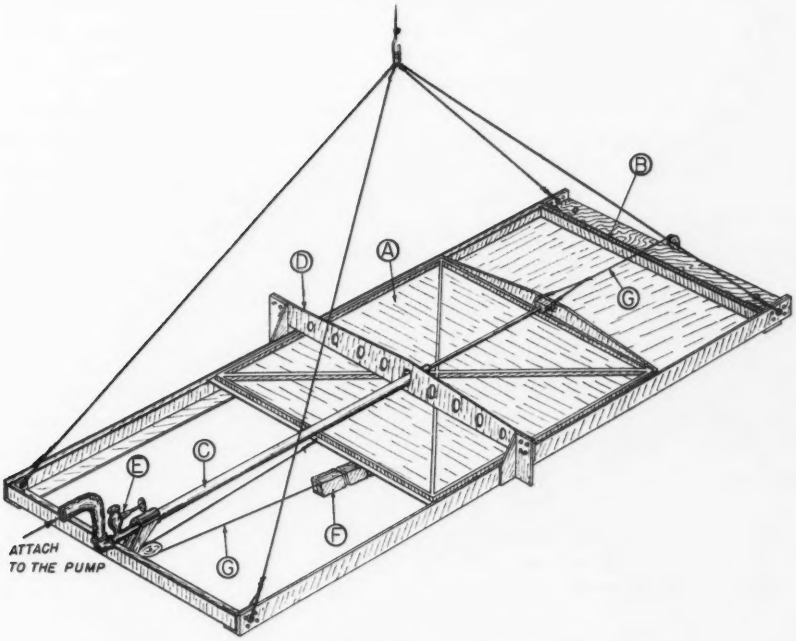

FIG. 3. Drawing showing construction details.

Method of Operation

In practice, the apparatus is operated as follows: With the lid in the open position, the apparatus is lowered into the water in a horizontal position. Spanners should be placed in the cables so that tilting of the tray can be prevented by proper adjustments. Six enamelled, shallow trays are placed in the tray of the apparatus, and cover the square meter area completely. In Fig. 6, the tray of the apparatus is only partially uncovered, so that four of the six enamelled trays can be seen. On these trays, the descending material is collected.

An alternative to this method is the use of latex as a cover of the aluminum tray and its sides. The latex can be applied by a brush or spray gun. Coagulation may be hastened by the use of acetic acid. When properly applied, the latex forms a complete film on the bottom and sides of the tray which can later be peeled off in one piece, forming a "bag" containing the sediment. A sheet of thin rubber or plastic may also be used after proper leaching in pure water.

The apparátus is lowered into the water from a raft whose construction and characteristics are shown in Fig. 5. An opening slightly larger than the total dimensions of the collector is provided in the center of the raft. Through this opening, the apparatus can be lowered into the water suspended from a

pulley which is attached to a collapsible support made of galvanized tubing. The apparatus is lowered to the desired depth, after which the steel cable is attached to a buoy. A very satisfactory buoy can be made from a 35-gal. aluminum airplane wing tank which may be purchased from war surplus dealers, at a nominal cost. When it is desirable to make collections during the winter period under the ice cover, the buoy must be anchored by two cables in such a way that it will be held below the level of the ice cover. The free end of the rubber hose is also attached to the buoy. After the apparatus has been suspended, the raft is removed.

The sediment collector is left in the water during variable periods whose durations depend upon the purpose of the investigation, the rate of sedimentation, and the depth.

To lift the apparatus, the raft is placed so that the buoy is in the central opening of the raft. The free end of the rubber hose, which has been previously attached to the buoy, is now connected to a small hydraulic pump placed on the raft, and water is pumped into the hose. Fig. 8 shows this operation with the collector on the raft for demonstration purposes. The sliding lid is in a partially closed position. In order to ascertain whether the lid is closed, the author proceeds as follows: before the submersing of the collector, an empty, tightly closed bottle is attached to a piece of thin copper wire. This is fastened to the frame of the apparatus as well as to the open lid, by means of a loose loop. When the lid moves forward under the pressure of the pump, the thin wire breaks, and the bottle rises to the surface of the water, informing the operator that the lid is closed.

After the apparatus is closed, it is lifted and suspended above the raft. After releasing the pressure in the system by opening a valve (*G*, Fig. 1; *E*, Fig. 3; Fig. 7), the lid is pushed back into its open position. The trays containing the sediments are removed and their contents collected. Careful lifting is required to avoid losses of the sediments. The use of latex, or a rubber or plastic sheet, has the advantage of enabling the operator to remove all sediment from the tray without any loss. The hydraulic device on the sediment collector was suggested by Mr. Albert Courtemanche, member of the Biological Bureau, as a valuable improvement on the compressed air pump, originally designed by the author.

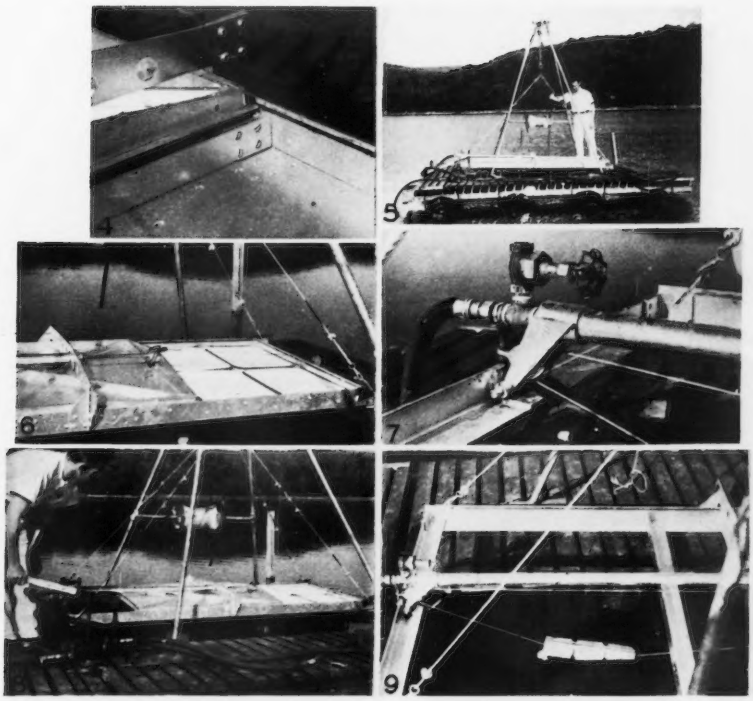

FIG. 4. Side wall of tray with groove for sliding lid.

FIG. 5. Collector on top of raft.

FIG. 6. Tray partially closed by lid under pressure of pump. Four of the six enamelled collecting trays are shown.

FIG. 7. Pressure release valve at end of cylinder. Note pin which allows vertical swing of cylinder.

FIG. 8. Water is pumped into cylinder. Lid is partially closed. Collector is on top of raft for demonstration.

FIG. 9. Collector in closed position. Weight moved to left to avoid tilt of apparatus. See text.

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